

Long-term sampling of a herpetofaunal assemblage on an isolated urban bushland remnant, Bold Park, Perth

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Abstract

Twenty-nine species of herpetofauna (three frogs, seven snakes and nineteen lizards) were recorded from an isolated urban bushland remnant, Bold Park, Perth. Four habitats were sampled by fenced pitfall trapping for a total of 398 days extending over seven years. There were marked differences in activity patterns of the herpetofauna through the year, with the greatest numbers trapped in November and December. Species trapped first in the sampling regime were also those most frequently captured; several species were not prone to pitfall trapping. Although sampling effort varied between years, in no single year were all 29 species trapped; on average only 79% of the assemblage was captured in any one year. About 100 individuals were captured before 50% of the total assemblage was recorded and around 200 individuals for 80% of the assemblage; this equates to between 360-480 pit-days and over 960 pit-days of trapping effort, respectively. These data have implications for the sampling regimes and analyses of surveys undertaken to document herpetofaunal assemblages for environmental impact assessments, conservation and management plans.

Introduction

The colonisation of Western Australia by Europeans in 1829 commenced a marked and irreversible alienation of natural ecosystems and their composite assemblages of fauna. This transformation of the landscape is profound in Perth, the major urban centre of Western Australia, which now accommodates nearly 1.2 million people and which has few remnants of the original ecosystems.

In 1978 the Western Australian Museum documented the fauna of the northern Swan Coastal Plain to determine, in part, the vertebrate fauna species still extant in the region and to evaluate the impact of the first 150 years of settlement on vertebrates. Some 20 species of mammals and six birds had become locally extinct since settlement (see How & Dell 1993). Further sampling was commenced in 1986 of three isolated bushlands in the inner urban areas of to determine the variation in the fauna across the major landform units and specifically of the *Banksia* woodlands on the Swan Coastal Plain (How & Dell 1989).

Analysis of these surveys and examination of data from several other site-specific faunal surveys showed a marked geographic patterning of the herpetofaunal assemblages on the landforms of the Perth area. This was related to both major landform types and geographic barriers (How & Dell 1994). The caveat that was applied to the data used in that analysis was that sampling had to have encompassed at least 10 days of intensive collection during the spring period. The sampling of the three inner urban bushland remnants, commenced in 1986, continued through until 1990 in two cases and until 1993 in the third. The aim of extending these surveys

was to determine the seasonal activity, annual variation and "total" assemblages of the herpetofauna in these remnants. I examine here the first seven years of sampling at Bold Park, the longest sampled of these three remnants, and illustrate the effort expended to adequately document the herpetofaunal assemblage

Methods

Bold Park is a bushland remnant of some 330 ha located close to the Indian Ocean about 10 km west of central Perth. The preliminary list of vertebrate species from Bold Park has already been published (How & Dell 1990).

This herpetofaunal survey of Bold Park was undertaken between December 1986 and June 1993 using four similar fenced pitfall traplines. The fenced pitfall traplines consisted of six pitfall traps placed in a line between 7 and 8 metres apart. Each pit trap consisted of a 17.5 cm diameter PVC pipe that was 60 cm deep and sealed at the bottom with fly-screen mesh. Drift fences that were 50 m long fly-screen mesh, 30 cm high and dug 5 cm into the substrate, crossed each of the 6 pitfall traps. Each pitfall trap open for 24 hours was referred to as a pit-day.

The four habitats selected for surveying represent the principal vegetation types and most of the vegetational heterogeneity of Bold Park determined by Keighery *et al.* (1990). These habitats were;

- BP1 Mixed coastal heath
- BP2 *Dryandra sessilis* shrubland
- BP3 *Banksia attenuata* / *B. menziesii* low woodland
- BP4 *Eucalyptus gomphocephala* (Tuart) woodland

The first of these sampling sites (BP1) was located on

Table 1

Number of days trapping and the number of individuals trapped for each month of each year between December 1986 and June 1993 at Bold Park. The mean number of individuals trapped daily during each month is also calculated. Twenty four pitfall traps were open each day at Bold Park.

	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	Total
86/87	-	-	-	-	-	4/62	0	4/25	4/17	0	4/13	4/3	20/120
87/88	0	0	5/20	6/38	12/191	6/103	8/49	6/32	6/22	6/17	0	0	55/472
88/89	0	0	6/16	10/33	6/92	14/225	7/56	0	7/45	6/19	0	0	56/486
89/90	0	0	0	25/64	5/52	10/94	10/52	4/14	0	16/82	0	0	70/358
90/91	0	0	0	8/20	17/182	2/30	0	15/56	14/38	0	0	0	56/326
91/92	0	0	0	0	10/115	12/151	7/51	10/47	2/14	0	8/2	0	49/380
92/93	0	0	0	0	27/171	30/277	8/49	14/52	12/30	1/2	0	0	92/581
total	0	0	11/36	49/155	77/803	78/942	40/257	53/226	45/166	29/120	12/15	4/3	398/2723
Ind/day			3.27	3.16	10.43	12.08	6.43	4.26	3.69	4.14	1.25	0.75	6.84
Ind/10pit-days			1.36	1.32	4.35	5.03	2.68	1.78	1.54	1.72	0.52	0.31	2.85

Table 2

Number of individuals of each species recorded in each habitat and during each year of the Bold Park sampling program.

	SITES				TOTAL	YEARS							
	BP1	BP2	BP3	BP4		86/87	87/88	88/89	89/90	90/91	91/92	92/93	
Trapping Days	398	398	398	398	398	20	55	56	70	56	49	92	
Pit-days	2388	2388	2388	2388	9552	480	1320	1344	1680	1344	1176	2208	
LEPTODACTYLIDAE													
<i>Heleioporus cyrei</i>	0	34	37	0	71	5	6	8	23	8	7	14	
<i>Limnodynastes dorsalis</i>	48	45	40	13	146	5	25	37	50	8	4	17	
<i>Myobatrachus gouldii</i>	2	7	11	5	25	0	1	5	10	1	0	8	
ELAPIDAE													
<i>Pseudonaja affinis</i>	0	1	0	0	1	0	0	0	1	0	0	0	
<i>Simoselaps bertholdi</i>	26	24	52	20	122	6	22	21	10	18	23	22	
<i>Simoselaps bimaculatus</i>	3	1	5	1	10	2	3	1	0	0	2	2	
<i>Simoselaps calonotos</i>	1	4	8	3	16	1	4	3	5	3	0	0	
<i>Simoselaps fasciolatus</i>	4	1	2	0	7	0	2	2	0	3	0	0	
<i>Simoselaps semifasciatus</i>	14	2	1	5	22	1	1	6	2	4	2	6	
TYPHLOPIDAE													
<i>Ramphotyphlops australis</i>	2	11	10	4	27	0	3	3	2	7	2	10	
AGAMIDAE													
<i>Pogona minor</i>	18	2	10	2	32	0	11	3	4	5	5	4	
<i>Tympanocryptis adelaidensis</i>	1	16	2	0	19	0	3	9	4	1	0	2	
GEKKONIDAE													
<i>Diplodactylus alboguttatus</i>	1	0	0	0	1	0	1	0	0	0	0	0	
<i>Diplodactylus spinigerus</i>	39	35	40	0	114	13	41	31	4	6	11	8	
PYGOPODIDAE													
<i>Aprasia repens</i>	3	2	0	14	19	0	4	2	1	3	1	8	
<i>Lialis burtonis</i>	20	24	36	4	84	2	25	6	7	8	20	16	
SCINCIDAE													
<i>Cryptoblepharus plagiocephalus</i>	0	4	3	20	27	3	8	2	5	2	2	5	
<i>Ctenotus fallens</i>	226	81	109	47	463	35	83	68	54	63	74	86	
<i>Ctenotus lesueurii</i>	48	3	8	0	59	10	13	18	3	3	5	7	
<i>Cyclodomorphus celatus</i>	12	0	0	0	12	1	2	4	2	1	1	1	
<i>Hemiergus quadrilineata</i>	112	267	334	285	998	11	131	169	114	141	160	274	
<i>Lerista elegans</i>	33	40	36	67	176	10	28	30	24	25	21	38	
<i>Lerista lineopunctulata</i>	62	38	43	21	164	6	35	20	11	24	29	39	
<i>Lerista praepedita</i>	2	6	9	0	17	0	2	2	3	2	1	7	
<i>Menetia greyii</i>	4	5	7	24	40	6	7	6	8	8	3	2	
<i>Morethia lineocellata</i>	0	0	1	0	1	0	0	1	0	0	0	0	
<i>Morethia obscura</i>	0	0	2	0	2	0	0	2	0	0	0	0	
<i>Tiliqua rugosa</i>	15	15	6	7	43	2	10	9	8	6	7	3	
VARANIDAE													
<i>Varanus gouldii</i>	2	1	1	0	4	0	1	0	1	1	0	2	
Individuals	698	669	813	542	2722	120	472	486	358	326	380	581	
Species	24	25	25	17	29	18	25	25	25	24	21	23	

Table 3

The mean number of captures of species in the various taxonomic categories comprising the entire herpetofaunal assemblage at Bold Park. The mean number of days of trapping to first capture of the species and the mean number of individuals of other species captured prior to first capture of a species are also presented. Means are presented with standard deviation, and sample size in parentheses. Twenty four pit-days occurred on each day of trapping at Bold Park.

TAXON	Captures	Days to first capture	Individuals of other species
Frogs	80.7 ± 61.1(3)	11.3 ± 8.5(3)	81.0 ± 46.9(3)
Snakes	29.3 ± 41.8(7)	41.1 ± 66.0(7)	293.3 ± 487.1(7)
Lizards	120.1 ± 239.3(19)	25.7 ± 36.4(19)	186.1 ± 280.0(19)
Skinks	167.3 ± 293.4(12)	26.2 ± 44.8(12)	203.3 ± 346.1(12)

the sands of the near-coastal Quindalup Dune landform and the remainder (BP2-4) were located on the adjacent and more easterly Cottesloe sands of the Spearwood Dune landform.

Spearman Rank Correlation analysis of the data was undertaken using the Statistix (1996) software package. The species accumulation graphs for species/individuals was undertaken using Microsoft Excel.

Results

Herpetofauna assemblage

A total of 398 days of trapping (2388 pit-days) was undertaken in each of the four habitats resulting in 2722 captures of 29 species during the years 1986 to 1993.

The duration and intensity of trapping varied between years (Table 1). During the first two years of the study, sampling was undertaken for short periods (4-7 days) at regular intervals. This regime indicated that a pronounced activity peak occurred for the majority of the species during the spring-early summer period. Sampling was intensified around this period during subsequent years, but greater effort was also expended in late summer-early autumn when the young of many reptile species hatch and become active.

The 29 species trapped comprised three frogs, six front-fanged snakes, a blind snake, two dragons, two legless lizards, two geckos, 12 skinks and a monitor (Table 2). Several species were infrequently captured by the pitfall trapping regime of the survey. Larger species, such as Gould's monitor (*Varanus gouldii*) and dugite (*Pseudonaja affinis*) were rarely trapped although they were occasionally sited and their tracks were frequently observed. The arboreal marbled gecko (*Phyllodactylus marmoratus*) was frequently observed during nocturnal searches with head-torches, but was not pitfall trapped. The legless lizard *Pletholax gracilis* is known from only six captures made in a floristically rich heath in the centre of Bold Park (Jiang, Kunming Institute of Zoology, pers comm). All trapezines were over 500 meters from the nearest freestanding water and it appears that this precluded the capture of several additional species of frog known from the nearby Perry Lakes.

The study extended for nearly 7 years and around 400 trapping days and, since no additional species were trapped for the last 210 days (1336 captures) of trapping, it was assumed that the total assemblage of Bold Park had been recorded.

Species collected earlier during the trapping regime were also those that were most common in the sampled assemblage. This is reflected by the strong negative correlation (Spearman Rank Correlation -0.8304, $P < 0.01$) between the number of captures of each of the 29 species and the sequence of first capture of that species in the total assemblage.

The average number of captures for each species in each of the various taxonomic categories is presented in Table 3 for the complete assemblage. The average number of days trapping before a species was first captured and the mean number of individuals of other species caught prior to the first capture of a species is also presented. Snakes were less frequently captured than lizards either because they are less abundant or because they are not as prone to capture in pitfall traps.

The effort expended to document the assemblage and the proportion of the assemblage documented after selected effort intervals or individuals trapped is

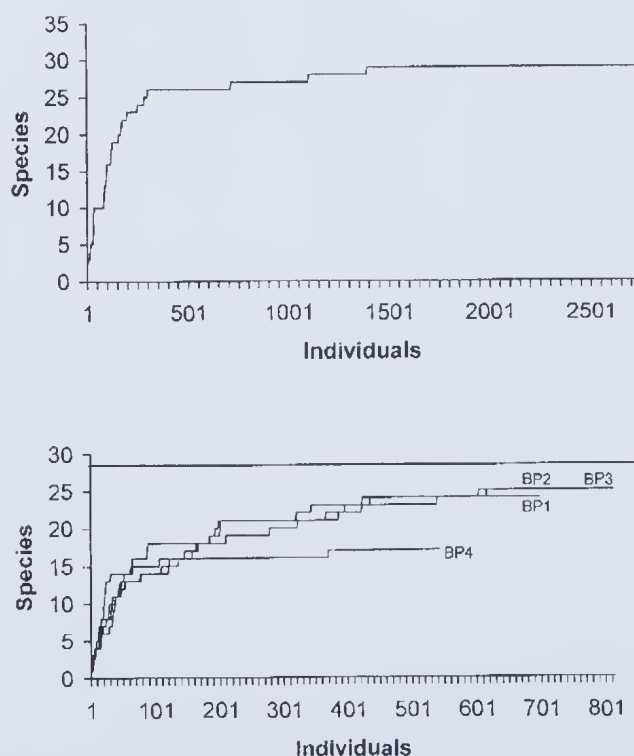


Figure 1. Species accumulation curves for the total herpetofaunal assemblage at Bold Park (top) and the herpetofaunal assemblages of the four habitats (BP1-4) sampled (bottom).

Table 4

The number of species captured at Bold Park after selected intervals of trapping and their percentage of the total assemblage documented. Data are presented for both all herpetofauna and only lizards and using both the number of trapping days and the number of individuals trapped for the assemblages in each habitat as well as all of Bold Park. Six pit-days occurred for every day of trapping in each habitat and 24 pit-days every day for all of Bold Park.

	BP1	BP2	BP3	BP4	Mean % ± SD	Total
HERPETOFAUNA						
Days						
10	7-29%	7-28%	8-32%	7-41%	32.5±5.9	13-45%
20	11-46%	9-36%	9-36%	9-53%	42.8±8.3	18-62%
30	13-54%	14-56%	12-48%	10-59%	54.3±4.7	20-69%
40	16-67%	14-56%	14-56%	13-76%	63.8±9.7	24-83%
50	18-75%	15-60%	16-64%	14-82%	70.3±10.0	26-90%
75	18-75%	16-64%	18-72%	14-82%	73.3±7.5	26-90%
100	21-88%	18-72%	21-88%	16-94%	85.5±9.4	27-93%
150	21-88%	19-76%	22-88%	16-94%	86.5±7.6	28-97%
200	22-92%	21-84%	23-92%	16-94%	90.5±4.4	29-100%
250	24-100%	23-92%	24-96%	16-94%	95.5±3.4	29-100%
Individuals						
25	6-25%	13-52%	8-32%	8-47%	39.0±12.6	5-17%
50	13-54%	14-56%	12-48%	13-77%	58.8±12.6	10-35%
100	18-75%	15-60%	14-56%	14-82%	68.3±12.3	16-55%
150	18-75%	16-64%	17-68%	16-94%	75.3±13.3	19-66%
200	20-83%	18-72%	19-76%	16-94%	81.3±9.6	23-79%
250	21-88%	19-76%	21-84%	16-94%	85.5±7.6	23-79%
300	21-88%	20-80%	21-84%	16-94%	86.5±6.0	25-86%
350	21-88%	21-84%	22-88%	16-94%	88.5±4.1	26-90%
400	23-96%	22-88%	23-92%	17-100%	94.0±5.2	26-90%
Total spp	24	25	25	17		29
LIZARDS						
Days						
10	6-38%	6-40%	6-38%	5-50%	41.5±5.8	10-53%
20	8-50%	6-40%	6-38%	6-60%	47.0±10.1	11-58%
30	10-63%	9-60%	8-50%	7-70%	60.8±8.3	12-63%
40	13-81%	9-60%	9-56%	9-90%	71.8±16.4	15-80%
50	14-88%	10-67%	10-63%	9-90%	77.0±14.0	17-90%
75	14-88%	11-73%	11-69%	9-90%	80.0±10.6	17-90%
100	15-94%	13-87%	13-81%	9-90%	88.0±5.5	18-95%
150	15-94%	13-87%	14-88%	9-90%	89.7±3.1	19-100%
200	15-94%	14-93%	15-94%	9-90%	92.8±1.9	19-100%
250	16-100%	14-93%	16-100%	9-90%	95.8±5.1	19-100%
Individuals						
25	5-31%	9-60%	6-38%	6-60%	47.3±15.0	5-26%
50	10-63%	9-60%	8-50%	9-90%	67.8±17.1	8-42%
100	14-88%	10-67%	9-56%	9-90%	75.3±16.5	11-58%
150	14-88%	10-67%	10-63%	9-90%	77.0±14.0	12-63%
200	15-94%	12-80%	11-69%	9-90%	83.3±11.2	14-74%
250	15-94%	12-80%	13-81%	9-90%	86.3±6.9	14-74%
300	15-94%	13-87%	13-81%	9-90%	86.3±6.9	16-84%
350	15-94%	13-87%	15-94%	9-90%	91.3±3.4	17-90%
400	15-94%	13-87%	15-94%	9-90%	91.3±3.4	17-90%
Total spp	16	15	16	10		19

presented in the final column of Table 4. These data indicate that around 100 individuals need to be captured before 50% of the total assemblage is documented while around 200 individuals are needed to document 80% of the assemblage. This translates to between 360-480 pit-days for 50% of the assemblage to be recorded and around 960 pit-days for 80% of the assemblage to be recorded.

When only the lizard assemblage is considered, 80% of the species are documented between 250 and 300 captures or around 960 pit-days of trapping. The species accumulation graphs for the total assemblage and the assemblages in each habitat are plotted in Fig 1.

Variation between habitats

Distinct habitat preferences were exhibited by many

Table 5

The percentage of the total herpetofaunal assemblage of 29 species trapped after successive 10-day intervals during each of the seven years of the Bold Park trapping study. Mean and standard deviation for the respective time intervals are also presented.

DAYS	86/87	87/88	88/89	89/90	90/91	91/92	92/93	Mean
10	44.8	51.7	31.0	37.9	34.5	51.7	48.3	42.8 ± 8.4
20	62.1	75.9	65.5	51.7	58.6	58.6	65.5	62.6 ± 7.6
30	-	82.8	79.3	65.5	72.4	69.0	65.5	72.4 ± 7.3
40	-	86.2	86.2	75.9	79.3	72.4	69.0	78.2 ± 7.1
50	-	86.2	86.2	79.3	82.8	72.4	75.9	80.5 ± 5.6

of the species. Only 15 of the 29 species (52%) were captured in all four habitats surveyed at Bold Park (Table 2).

Species such as the gecko *Diplodactylus albobuttatus*, and the skinks *Morethia lineocellata*, *M. obscura* and *Cyclodomorphus celatus*, are uncommon in Bold Park, with both a restricted habitat preference and low abundance. Dugites (*Pseudonaja affinis*), although captured in only one habitat, occurred throughout the Park and the tracks of large adults were recorded in every habitat. A yearling was captured in the pitfall traps. The Tuart woodland (BP4) site was considerably less species rich than were the other three sites, principally due to the absence of 5 species of skinks.

No new species were added to the assemblage lists of the habitats for the last 174 days of trapping for BP1, 51 days for BP2, 91 days for BP3 and 139 days for BP4. This equated to 274, 65, 197 and 172 captures, respectively. In each of these habitats six pitfall traps were operated each day.

For the assemblages recorded in each of the four habitats the correlation between the number of individuals of each of the 91 species populations documented and their capture sequence was strongly negative (Spearman Rank Correlation -0.8274, $P < 0.01$) again indicating that the more common species are trapped first.

Although 54% of the assemblage was usually documented by day 30 (180 pit-days), between 75 and 100 trapping days (450 - 600 pit-days) were needed to document 80% of the herpetofaunal assemblage in each habitat (Table 4). On average, nearly 60% of the herpetofaunal assemblages in habitats were documented after 50 captures, while 80% of the assemblages were documented before 200 captures. For just the lizard assemblages of the four habitats, the average effort needed to record 80% of the assemblage was 150-200 captures or 75 days.

Variation Between Years

Over the seven years there was pronounced variation in the assemblages recorded for Bold Park (Table 2). The number of species documented varied from 18 in 1986/1987 (only 20 trapping days) to 25 for the year's 1987/1988, 1988/1989, and 1989/1990. Fewer species were trapped in 1992/1993 when trapping effort was far greater (see Table 1) and focussed on the peak activity period of November -December. The mean percentage of the herpetofauna documented during a year was $79.31 \pm 0.09(7)$ percent (Table 2).

There were extended periods of time between captures for some species in Bold Park, with over three years occurring between retrapping *Simoselaps bimaculatus* in the middle of the study, while *S. calanotos* and *S. fasciolatus* were not retrapped in the last 28 months of the study. These long absences from the trap record impact on the annual documentation of the herpetofauna assemblage as do the limited captures of uncommon or restricted species in Bold Park, such as *Diplodactylus albobuttatus*, *Morethia lineocellata* and *M. obscura*.

During the six years when trapping effort extended near or over 50 days, the average percentage of the herpetofauna community recorded was only around 80% (Table 5).

Discussion

This long-term survey of the herpetofauna of an isolated bushland remnant in Perth has indicated that a significant effort is required to adequately document the diverse assemblage that exists.

A period of peak activity occurs amongst the herpetofauna during November- December with reduced activity either side of this period and much reduced activity between late-autumn and early spring (Table 1). James (1994) has documented strong seasonal patterns of activity centred on the spring period previously for herpetofauna assemblages in his extensive examination of a central Australian lizard assemblage. He also reported recording 91% and 86% of the lizard assemblage during successive spring census periods.

The reptile assemblage recorded by fenced pitfall trapping at Woodstock Station in the Pilbara (How *et al.* 1991) was 39 species. That survey, which extended over 58 days of pitfall trapping, nine trapping periods, three years and eight discrete habitats, revealed that 25 trapping days (1002 pit-days) elapsed before 80% of the pitfall trapped assemblage was recorded. However, the assemblage revealed by pitfall trapping represented only 58% of the 67 reptile species recorded by all means during the survey (How *et al.* 1991). In a recent survey of the lizard and snake fauna in arid Western Australia, Thompson (1996) recorded most of the 31 species of lizard and eight species of snakes in the first 10 days of trapping, while James (1994) had captured 32 lizard species (82%) after 30 days of trapping, 36 species (92%) after 61 days and all 39 after 180 days in central Australia. These returns for effort are considerably higher than that recorded for the lizard assemblage or even the entire herpetofaunal assemblage documented during the present study in Bold Park where 80% of the

total assemblage was recorded only after 40 days (960 pit-days) of trapping. For specific habitats in Bold Park the mean effort expended to record 80% of the assemblage was over 75 days (450 pit-days) for both the herpetofauna and the lizards (Table 4).

This survey has shown that the widespread and common species are also the first captured in the trapping sequence. Uncommon species with restricted habitat preferences are usually the focus of conservation and management programs; such species are generally captured later in the trapping sequence and will probably be missed by short term or low intensity surveys.

Government agencies responsible for auditing the environmental impacts of major developmental projects on faunal communities and assemblages provide guidelines to developers, which are invariably vague and usually stated in broad generalities. If faunal surveys are undertaken, these are generally of short duration and superficial, accounting for little of the annual and seasonal variation inherent in faunal activity. There are few data or long-term studies that assess procedures and methodology for documenting faunal assemblages (Anon 1984; Myers *et al.* 1984); consequently, the potential impact of developments on faunal populations and assemblages cannot be adequately assessed.

The principal finding of this study is that an extensive sampling effort is required in both temporal and spatial scales before the composition of an herpetofaunal assemblage (including its rarer species) can be adequately determined. This knowledge is essential to the proper evaluation of environmental impact statements and for species conservation and management plans.

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